

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
8 January 2004 (08.01.2004)

PCT

(10) International Publication Number
WO 2004/003446 A1

(51) International Patent Classification⁷: **F25D 23/06**

[US/US]; 1775 Meadow Grove, St. Joseph, MI 49085 (US). **MARTINELLA, Luigi** [IT/IT]; Via Risorgimento 127, I-28823 Ghiffa (IT). **GIUDICI, Giorgio** [IT/IT]; Via Fiume 6, I-21015 Lonate Pozzolo (IT).

(21) International Application Number:
PCT/EP2003/006865

(22) International Filing Date: 27 June 2003 (27.06.2003)

(74) Agent: **GUERCI, Alessandro**; Whirlpool Europe s.r.l., V.le G. Borghi 27, I-21025 Comerio (IT).

(25) Filing Language: English

(26) Publication Language: English

(81) Designated States (*national*): BR, CA, CN, CZ, IN, JP, KR, MX, NZ, PL, RU, US, ZA.

(30) Priority Data:
02014061.2 1 July 2002 (01.07.2002) EP

Published:
— with international search report
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

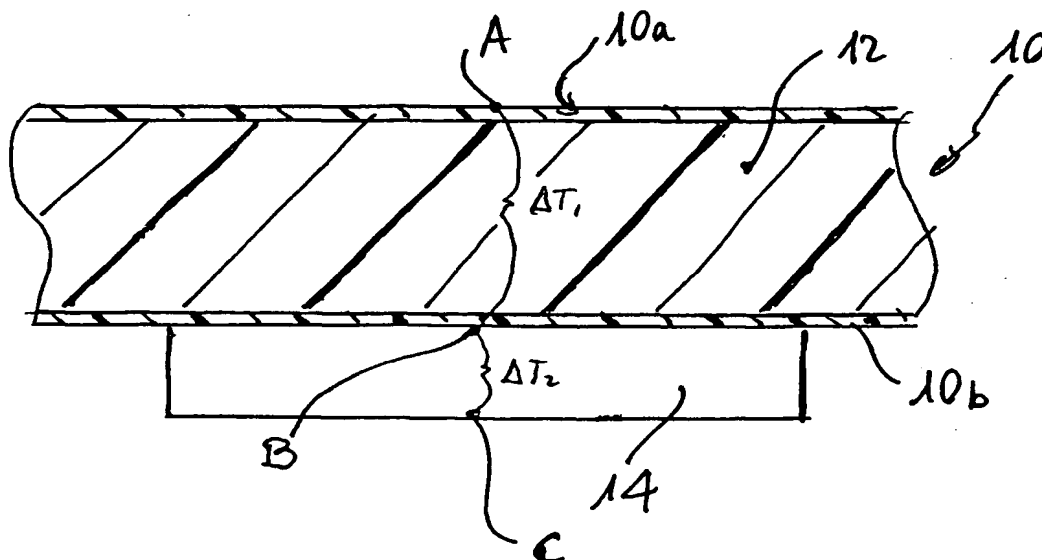
(71) Applicant (*for all designated States except US*):
WHIRLPOOL CORPORATION [US/US]; 2000 M 63, Benton Harbor, MI 49022 (US).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **KIRBY, David**

(54) Title: A VACUUM INSULATED REFRIGERATOR CABINET AND METHOD FOR ASSESSING THERMAL CONDUCTIVITY THEREOF



(57) Abstract: A vacuum insulated refrigerator cabinet comprises an evacuation system for evacuating an insulation space (10) of the cabinet when pressure inside such space is higher than a predetermined value. It comprises a sensor device having an insulation reference element (14) located on one side of said insulation space (10) and temperature sensors (A, B, C) for assessing the differences of temperature (ΔT_1 , ΔT_2) across the insulation space (10) and across the insulation reference element (14), such sensor device being suitable for providing the evacuation system with a signal related to the ratio of the above differences of temperature.

WO 2004/003446 A1



•

•

•

•

A VACUUM INSULATED REFRIGERATOR CABINET AND METHOD FOR ASSESSING THERMAL CONDUCTIVITY THEREOF

The present invention relates to a vacuum insulated refrigerator cabinet comprising an evacuation system for evacuating an insulation space of the cabinet when pressure inside such space is higher than a predetermined value. With the term "refrigerator" we mean every kind of domestic appliance in which the inside temperature is lower than room temperature, i.e. domestic refrigerators, vertical freezers, chest freezer or the like. A vacuum insulated cabinet (VIC) for refrigeration can be made by building a refrigeration cabinet that has a hermetically sealed insulation space and filling that space with a porous material in order to support the walls against atmospheric pressure upon evacuation of the insulation space. A pump system may be needed to intermittently re-evacuate this insulation space due to the intrusion of air and water vapour by permeation. A solution of providing a refrigerator with a vacuum pump running almost continuously is shown in EP-A-587546, and it does increase too much the overall energy consumption of the refrigerator. It is advantageous for energy consumption to re-evacuate only when actually needed. Therefore there is in the art the need of a simple and inexpensive insulation measurement system that would be applicable to operate a refrigerator cabinet vacuum pump or similar evacuation system only when actually needed.

The present invention provides a vacuum insulated refrigerator cabinet having such insulation measurement system, according to the appended claims.

According to the invention the sensor system is a system that compares the insulating value of the vacuum insulated cabinet to a standard insulation. Temperature measurements are made all at the same point on the cabinet. A pad of a material with known properties, preferably a standard non-ageing insulation, covers this point. The insulation performances of such standard insulation do not preferably change with time. Non-ageing insulators would be for instance rigid, open celled PU and rigid glass fibre insulation. Closed cell insulation such as PS or PU is less preferred since their insulation performances may change with age due to change in cell gas composition. The

temperature measurements are preferably made at a point on or near the outer surface of the insulation pad, at the interface of the pad and the cabinet liner (or alternatively to the wrapper, i.e. the outside surface of the cabinet) and at a point the opposite side from the pad. The temperature difference across the pad is compared to the temperature difference across the vacuum insulation. When the ratio of the temperature differences changes, it will indicate that the vacuum insulation is deteriorating. A criterion for vacuum pump operation based on this temperature ratio will assure that the insulation is always operating in an efficient manner. The function of the sensor system according to the invention is not affected by changing ambient conditions, as it would be affected a sensor system based on temperature values. Anyway, due to such changing ambient conditions, averages may have to be taken. Any of various temperature measuring devices may be used, some of which can measure the differences directly. Thermocouples and resistance thermometers are useful examples of such devices.

The invention will now be explained in greater detail with reference to drawings, which show:

- Figure 1 is a schematic cross-view of a vacuum insulated cabinet according to the invention;
- Figure 2 is an enlarged view of a detail of figure 1; and
- Figure 3 is a schematic diagram showing the relationship between the ratio of temperature differences across the cabinet and across the insulation pad and the insulation performances.

With reference to figures 1 and 2, a refrigerator cabinet comprises a insulated double wall 10 comprising two relatively gas impervious walls 10a (liner) and 10b (wrapper) filled with an insulation material 12 that can be evacuated. Both liner 10a and wrapper 10b may be of polymeric material. The insulation material 12 can be an inorganic powder such as silica and alumina, inorganic and organic fibres, an injection foamed object of open-cell or semi-open-cell structure such as polyurethane foam, or a open celled polystyrene foam that is extruded as a board and assembled into the cabinet. The insulation material 12 is connected to a known evacuation system (not shown) that can be a physical

adsorption stage (or more stages in series) or a mechanical vacuum pump or a combination thereof.

According to the invention, on the wrapper 10b of the double wall 10 it is glued or soldered an insulation pad 14 of a standard, non-ageing insulation, for instance a rigid glass fibre pad. Temperature sensors, such as thermocouples, are placed at points A, B and C of figure 2 and they are connected to a central process unit of the appliance (not shown) in order to provide it with a ratio $\Delta T_1/\Delta T_2$ between temperature difference across points A, B and B, C respectively.

In the central process unit of the appliance every ratio $\Delta T_1/\Delta T_2$ is compared to a minimum threshold value indicative of an increased pressure inside the cabinet double wall 10. In figure 3 there is an indication of how the heat transmission coefficient λ changes with time, showing an increase of pressure inside the double wall. In figure 3 the threshold value of $\Delta T_1/\Delta T_2$ is indicated with reference K.

A technical explanation behind the above behaviour may be found in the Fourier's law for heat diffusion $q = k \times A \times \partial T / \partial n$ (for steady-state heat diffusion across the refrigerator walls), solved for one-dimensional conditions as is typically the case in domestic refrigerators where one of the dimensions (thickness) is usually much smaller than the other two (height and width). Fourier's law reveals that the temperature ratio of the differential temperatures across the vacuum wall and across a pad of standard insulation – $\Delta T_1/\Delta T_2$ – can be ultimately expressed as $((k_2 \times l_1)/(k_1 \times l_2))$, where "k" stands for the thermal conductivity, and "l" stands for thickness.

From that, it is immediately evident that by keeping all the terms constant but k_1 , the parameter described in the present invention to measure the insulation characteristics – again, $\Delta T_1/\Delta T_2$ – will increase as k_1 decreases, and will decrease as k_1 increases, as shown in fig. 3.

Some other observations may be made regarding the measurement system according to the present invention. Under steady state conditions, the equation $\Delta T_1/\Delta T_2$ is independent on temperatures inside the refrigerator and that of the ambient, so appropriately reflecting the variation of the "k factor" (thermal conductivity) of the vacuum insulation.

By increasing the thickness of the pad 14, or decreasing its thermal conductivity, the accuracy of value calculated by equation $\Delta T_1/\Delta T_2$ will improve. Secondly, although the proposed scheme does not depend upon the temperature history of the measured sites, it may be sensitive to transient.

In order to eliminate or reduce the above side effects, it is preferred to define a trigger value for vacuum pump switching-on based on a 10 % increase in k value.

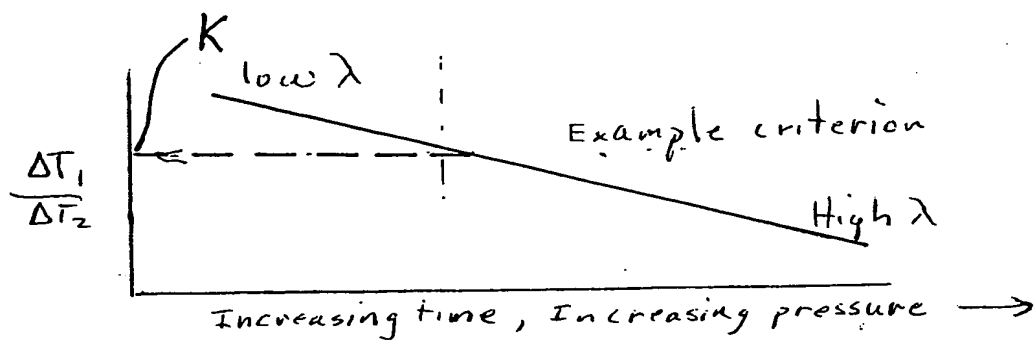
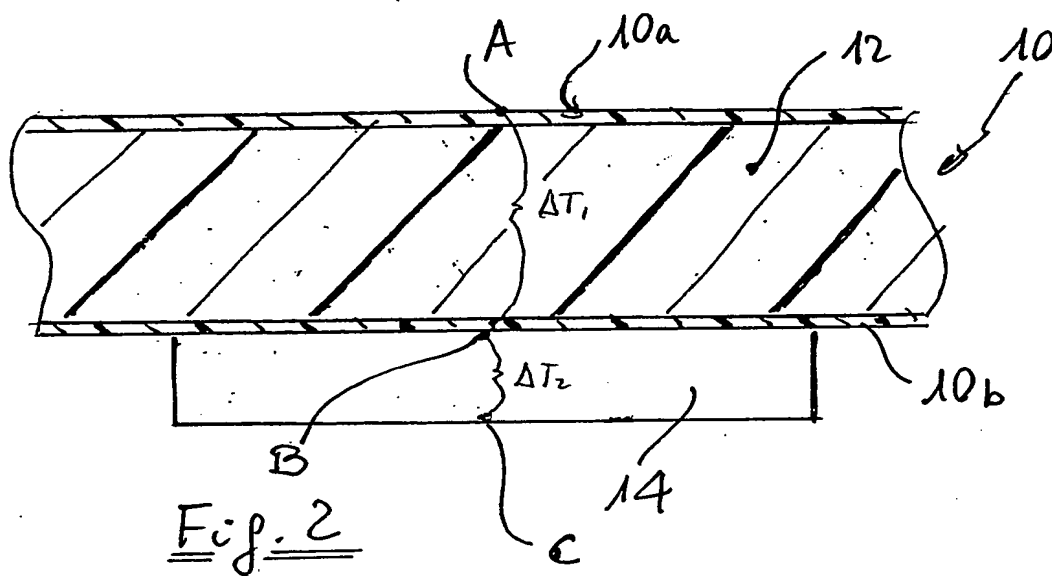
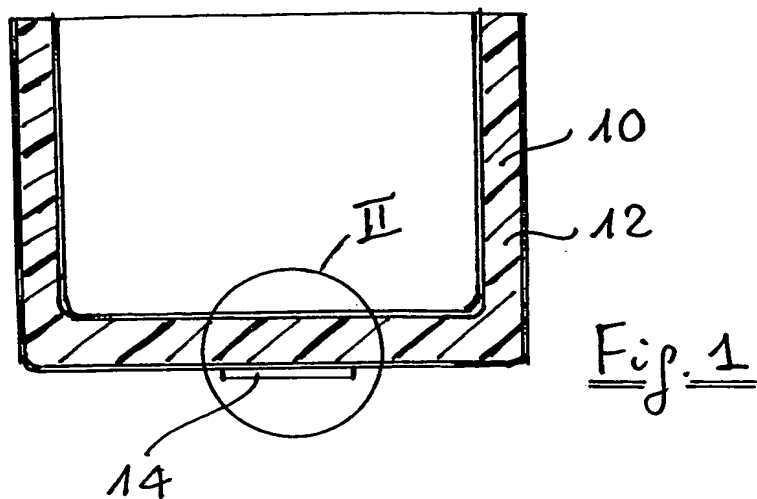
This may be suitable from insulation maintenance standpoint, and could be implemented with reasonable accuracy.

Moreover it is preferred to use a "standard insulation pad" as thick as possible and with the lowest possible thermal conductivity (k) for the sake of temperature measurement accuracy. Thermistors for temperature measurement should be preferably chosen with accuracy better than 0.2 °C, and door opening effect should be preferably eliminated through door sensors for awareness of "door status". As an alternative, it is possible to use the strategy of several consecutive measurements for confirming the degradation of the thermal insulation (vacuum degradation) and avoid the peaks in $\Delta T_1/\Delta T_2$ value since the door opening effect tend to be concentrated in a short period of time and vanishes quickly. If ambient temperature variation can be an issue (as for example in locations close to air conditioning/heating outlets), an external temperature sensor can help to purge those variations off the $\Delta T_1/\Delta T_2$ calculation.

CLAIMS

1. A vacuum insulated refrigerator cabinet comprising an evacuation system for evacuating an insulation space (10) of the cabinet when pressure inside such space is higher than a predetermined value, characterised in that it comprises a sensor device having an insulation reference element (14) located on one side of said insulation space (10) and temperature sensors (A, B, C) for assessing the differences of temperature (ΔT_1 , ΔT_2) across the insulation space (10) and across the insulation reference element (14), such sensor device being suitable for providing the evacuation system with a signal related to the ratio of the above differences of temperature.
2. A vacuum insulated refrigerator cabinet according to claim 1, characterised in that the insulation reference element (14) is located on the external side of the cabinet.
3. A vacuum insulated refrigerator cabinet according to claim 1 or 2, characterised in that temperature sensors are three thermocouples (A, B, C) located on a surface of the insulation space (10) opposite the insulation reference element (14), between the insulation space and the insulation reference element and on a surface of the insulation reference element opposite the insulation space.
4. A vacuum insulated refrigerator cabinet according to claim 1 or 2, characterised in that temperature sensors (A, B, C) are resistance thermometers.
5. A vacuum insulated refrigerator cabinet according to claim 4, characterised in that temperature sensors (A, B, C) have an accuracy at least of 0,2°C.
6. A vacuum insulated refrigerator cabinet according to claim 1, characterised in that the evacuation system is adapted to be triggered when the ratio of the above difference of temperature corresponds to a change in heat transfer coefficient higher than 10%.
7. Method for assessing the pressure inside an insulation space (10) of a vacuum insulated cabinet of a refrigerator, characterised in that it comprises the steps of evaluating the differences of temperature across

the insulation space (10) and across an insulation reference element (14) placed on a side of such insulation space, such evaluation being carried out on the same zone of the vacuum insulated cabinet where the insulation reference element is also placed, and providing a control system of the refrigerator with a signal related to the ratio ($\Delta T_1/\Delta T_2$) of the above differences of temperature, such ratio being indicative of pressure value inside the insulation space.



INTERNATIONAL SEARCH REPORT

International Application No.

PCT/EP 03/06865

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F25D23/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F25D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 587 546 A (ELECTROLUX RES & INNOVATION) 16 March 1994 (1994-03-16) cited in the application	1,2,4,5
A	column 3, line 7 - line 20; claim 6; figure 1	7
Y	DE 100 06 878 A (SCHOLZ FLORIAN) 6 September 2001 (2001-09-06)	1,2,4,5
A	column 4, line 20 - column 5, line 54; figures 1,2	7
A	DE 23 65 900 A (SEID MANFRED ING GRAD) 30 September 1976 (1976-09-30) claim 1; figure 1	1,7
A	EP 0 633 420 A (GETTERS SPA) 11 January 1995 (1995-01-11) column 8, line 4 - line 22; figure 2	1,7

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- *S* document member of the same patent family

Date of the actual completion of the international search

14 October 2003

Date of mailing of the international search report

30/10/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Jessen, F

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/EP 03/06865

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0587546	A	16-03-1994	SE 470463 B	18-04-1994
			DE 69305605 D1	28-11-1996
			DE 69305605 T2	27-03-1997
			EP 0587546 A1	16-03-1994
			JP 3391511 B2	31-03-2003
			JP 6194028 A	15-07-1994
			SE 9202607 A	11-03-1994
			US 5361598 A	08-11-1994
DE 10006878	A	06-09-2001	DE 10006878 A1	06-09-2001
			WO 0161118 A1	23-08-2001
			EP 1255898 A1	13-11-2002
			US 2003046894 A1	13-03-2003
DE 2365900	A	30-09-1976	DE 2365900 A1	30-09-1976
EP 0633420	A	11-01-1995	IT 1264692 B1	04-10-1996
			AT 151157 T	15-04-1997
			CA 2126815 A1	09-01-1995
			CN 1103151 A ,B	31-05-1995
			DE 69309453 D1	07-05-1997
			DE 69309453 T2	10-07-1997
			EP 0633420 A2	11-01-1995
			ES 2101281 T3	01-07-1997
			JP 7145778 A	06-06-1995
			RU 2120686 C1	20-10-1998
			US 5625742 A	29-04-1997

